# DENTAL VIDEO IMAGING SYSTEM

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of U.S. Provisional Patent Application No. 60/195,558 filed on April 6, 2000.

## BACKGROUND OF THE INVENTION

**[0002]** The present invention is related generally to the field of video imaging systems. Specifically, the present invention is related to a dental video imaging system that has camera control unit (CCU) circuitry for the video camera incorporated within the camera handpiece.

**[0003]** Video cameras for imaging dental anatomy are well known in the market place and described in the prior art. For example, Cooper in US 5,702,249, which is incorporated herein by reference, describes DENTSPLY's Acucam® Dental Imaging Camera. These imaging cameras consist of a handpiece having a distal end that contains optics and a sensor assembly for acquiring an image of dental anatomy either intra- or extra-orally. The acquired image is typically transmitted to a docking module for a docking station or directly to an interface unit using a cable with 16 or more wires for subsequent processing before the image is displayed to the clinician. The length of the cable between the handpiece and the docking module or the interface unit is usually restricted to 2 or 3 meters before the degradation of sensor pulses starts to substantially affect the quality of the image.

**[0004]** Figure 7 illustrates an arrangement of a docking module and docking station as used with a conventional camera. The conventional camera 702 is connected to a docking module 704 that contains a CCU 706. The docking module 704 with the CCU 706 is then plugged into a docking station 708. The docking station 708 is connected to a video monitor 710 for the clinician to view the images acquired with the conventional camera 702. Alternatively, the conventional camera 702 can be connected to an interface unit (not shown) that has a CCU 706. The interface unit would then be connected to the video monitor 710 for the clinician to view the images acquired with the conventional camera 702. Further, since much of the imaging needed is intra-oral, it is a continuing goal of the developing technology to miniaturize and make the components as small as possible.

[0005] Therefore what is needed is a dental imaging system that has a camera handpiece and associated cables that are reduced in size and can be used at larger distances from a docking station.

## SUMMARY OF THE INVENTION

[0006] The present invention is directed to a video camera imaging system for intra- and extra-oral imaging of dental anatomy. The dental video imaging system includes a housing having a handle portion and a distal end portion. The distal end portion has a view port for viewing intra- and extra-oral dental anatomy. An optical system is mounted in the distal end of the housing for acquiring, orienting and transmitting an image of the dental anatomy appearing in said view port. A sensor assembly, mounted in the distal end of the housing, converts images received through the optical system into video data signals. A camera control unit (CCU) or control circuit is mounted in the handle portion of the housing. The CCU includes a digital signal processor for receiving the video data image signal from the sensor and may have additional circuitry for providing an S-video, composite video or digital video signal output of the images. The dental video imaging system also includes a utility cable having cable components for conveying utilities (power and/or light) and control signals to the housing and for conveying video output data signals out of the CCU. Flexible cables are used for flexibly interconnecting the CCU with the sensor assembly and the utility cable. A docking station is also included for connecting the utility cable with the corresponding utilities and control signals and for receiving video output data signals for display or further processing.

[0007] A key feature and advantage of the present invention is the inclusion of the CCU within the handle portion of the handpiece to provide an S-video, composite video or digital video output, which output reduces the number of cable conductors and connections necessary for connecting the handpiece to a docking station. This arrangement results in a smaller cable of, for example, two to four connector wires, rather than the sixteen or more wires as has been previously required to output image data to a docking station or interface unit from a handpiece. In addition, this arrangement also permits the use of a longer camera cable between the handpiece and the docking station, which camera cable had been previously generally restricted to 2-3 meters.

**[0008]** Another advantage of the present invention is that the handpiece can be connected to a docking station or interface device by a simple connector without the need for a plug-in module containing the CCU.

**[0009]** Still another key feature and advantage of the present invention is that the CCU in the housing is interconnected with a CCD camera or other video sensor and a utility cable by means of flexible cables, preferably flexible printed circuits, or equivalent rigid connectors in such a manner that the CCD or sensor may be translated axially for focusing the desired dental object on the CCD or sensor.

**[0010]** Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** The present invention is described in greater detail below with reference to the following drawings:

Figure 1 is a plan view of an embodiment of the dental camera of the present invention for intra- or extra-oral imaging of desired objects of dental anatomy;

Figure 2 is a partial section elevational view of the dental camera of Figure 1 showing an arrangement of the CCD and CCU components of the present invention;

Figure 3 is an enlarged elevational cross sectional view of the focusing arrangement of Figure 2;

Figure 4 is a partial sectional elevational view of a second embodiment of a focusing arrangement of the present invention;

Figure 5 is a schematic partial sectional view of an alternate embodiment of the focusing arrangement of Figure 3;

Figure 6 is a schematic view of a video imaging system of the present invention;

Figure 7 is a schematic view of a prior art video imaging system; and

Figures 8 and 9 are alternate embodiments of the dental camera of the present invention.

[0012] Whenever possible, the same reference numbers will be used throughout the figures to refer to the same parts.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENT

[0013] Figures 1 and 2 illustrate an embodiment of a camera head or handpiece 100 of the present invention. The camera head 100 is preferably constructed using stainless steel components, however, other suitable materials can be used. The various body components of the camera head 100 are connected together to provide a watertight casing and are preferably epoxied or glued together.

[0014] A distal end of the camera head 100 includes a nose piece 102 that is gently curved at the tip for patient comfort. The nose piece 102 is preferably stainless steel, however, any other suitable material can be used for the nose piece 102. The nose piece 102 is connected via a cone section or transitional portion 104 to a larger diameter handle region 106. The handle region 106 is configured to provide the user with an improved grasping area and a superior torque characteristic and is preferably about 20 mm in diameter.

[0015] The cone section 104 is positioned between the nose piece 102 and the handle region 106 and includes four dimples 108, which are spaced about 90° apart, to provide an orientation guide for the clinician. When normally held, the clinician's index finger is located about 45° clockwise of vertical. The dimples 108 are positioned to aid orientation of the camera head 100, as follows:

| **Dimple Position** | **Direction of View** |
|---|---|
| 1:30 o'clock | down |
| 4:30 o'clock | right |
| 7:30 o'clock | up |
| 10:30 o'clock | left |

[0016] A focus mode ring 110 is located at the rear of the handle region 106 and is used to select one of the following mode presets:

| Mode | Position | Depth of Focus | Application |
|---|---|---|---|
| E | Fully CCW | 40mm to Infinity | Extra-oral use |

| | | | |
|---|---|---|---|
| W | 1st detent | 12mm to 40mm | Wide angle exam mode |
| C | 2nd detent | 8mm to 12mm | Close up exam mode |
| Macro | Continuous | 1mm to 8mm | Adjustable focus |

**[0017]** Figure 6 illustrates the camera head 100 being connected to a docking station or interface unit 600 via a small diameter connecting or utility cable 302. The docking station or interface unit 600 can then be connected to the video monitor 710 for display of the images acquired by the camera head or handpiece 100. The utility cable 302 preferably includes a spiral winding to strengthen the utility cable 302 and support any wires, fiber optic light guides, cables or conductors located therein. The spiral winding is preferably a steel spiral winding. In the embodiment shown in Figure 3, the utility cable 302 and the wires, fiber optic light guide, cables and conductors located therein are rigidly connected to the camera handpiece 100. However, in another embodiment of the present invention, the utility cable 302 and the wires, fiber optic light guide, cables and conductors located therein are detachably connected to the camera handpiece 100.

**[0018]** The docking station or interface unit 600 can be any type of device that can provide the camera head 100 with the appropriate power, control and/or light for operation and can then receive the image output signals from the camera head 100 for any additional processing and display. The diameter of the connecting cable 302 is between about 0.125 and about 0.5 inches and is preferably about 0.25 inches. A smaller diameter connecting cable 302 is possible because of a control circuit or camera control unit (CCU) board 202 located in the camera head 100 as shown in Figure 2. The CCU board 202 preferably provides an S-video output signal to a camera cable 304, located in the utility cable 302, having 4 wires for the conveying or transmitting the output signal, in contrast to the normal 16 or more wires which are usually required to convey or transmit an image output signal to a CCU located in or interface unit.

**[0019]** In conventional cameras, where the camera head sensor is connected to a CCU in a docking module that is plugged into a docking station or in an interface unit, the camera cable length is usually restricted to 2 or 3 meters. In contrast, in the case of the present invention, the S-video output signal from the CCU board 202 and camera cable 304 have no such restriction and the length of the connecting cable 302 is only restricted by the practical light guide limitation in fiber optic light guide 306 (see Figure 3) also located in connecting cable 302.

**[0020]** The CCU board 202 is a printed circuit board with a size and shape to enable its location within the camera head 100 and handle region 106. The CCU board 202 is preferably manufactured by Matsushita Communications, Inc. (MCI). The maximum permissible width of the CCU board 202 is 17 mm for location within a handle region 106 having a 20 mm outside diameter (OD). A discussed above, a 20 mm OD for the handle region 106 is preferable for optimum user comfort and control. As shown in Figure 2, the distal end of the CCU board 202 is tapered to fit within the conical section 104 that connects the nose piece 102 to the handle region 106. This provides additional area for the CCU board 202 without extending the length of the camera head 100.

**[0021]** The camera control unit board 202 includes a signal processor, which processes the signal from the image sensor 210. The signal processor is preferably a Digital Signal Processor (DSP), but can be an Analog Signal Processor. The CCU board 202 then generates the preferred S-video output signal from the CCU board 202 either from the signal processor or from additional circuitry on the CCU board 202. Additionally, in other embodiments the CCU board 202 can generate a component video or digital video output signal. It is to be understood that the wires in the camera cable 304 to transmit or convey the output signal correspond to the particular type of output signal from the CCU board 202. The signal processor is configured and adjusted by digital commands from a computer via 3 wires in the camera cable 304. This enables the CCU board 202 to be adjusted after the camera head 100 has been assembled and closed. Non-volatile memory on the CCU board 202 can be used to store the adjustments, thereby making the adjustments permanent.

**[0022]** As described above, the connecting or utility cable 302 includes the camera cable 304, which is preferably shielded, and the fiber optic light guide 306. The camera cable 304 is connected to a flexible printed circuit 308 by an encapsulated connection 310 in the camera head 100. The flexible printed circuit 308 is then connected to the CCU board 202 by a connector 312. The camera cable 304 includes wires or conductors to convey or transmit the following signals and information:

- power to the CCU board 202;
- computer control data to the CCU board 202; and
- video output signals from the CCU board 202.

[0023] Referring back to Figure 2, an image enters an optical system through a window 204 into a negative lens and a non-inverting prism 206. The window 204 is preferably sapphire, but can also be glass or acrylic. The non-inverting prism 206 is preferably a roof prism or double prism and reflects the image into a main lens assembly 208. The roof prism 206 is angled to obtain a 97.5° direction of view with respect to the optical axis. The negative lens enables a relatively wide angle of view of 62° horizontally through the window 204 by converting the wide angle to a narrow angle for the roof prism 206. This enables a wider viewing angle than can otherwise pass through the prism. It is to be understood that different directions of view and angles of view can be obtained by selecting the appropriate roof prism 206 and/or negative lens.

[0024] In another embodiment of the present invention, a simple inverting prism can be used in place of the non-inverting roof prism 206. In this embodiment, an inverted image is sent to the CCU board 202, which includes the appropriate circuitry to orient the image. In still another embodiment of the present invention, the use of the negative lens is not required, and a wide angle image can be sent by the optical system to the CCU board 202.

[0025] The main lens assembly 208 is housed in a barrel or enclosure that is connected to a thin-wall lens tube 212, preferably by gluing with epoxy. The lens tube 212 is held in place within the nose piece 102 by a lens holder spacer. The lens tube 212 is preferably stainless steel, although other suitable materials can be used. The preferred embodiment of the main lens assembly 208 includes three elements: a plano-convex lens; a doublet; and a simple lens. The simple lens focuses the image onto an image sensor 210. The image sensor 210 is preferably a ¼-inch, high resolution CCD. However, other types of images sensors can be used such as CMOS devices and active pixel sensors (APS).

[0026] To supply light to the camera head 100, one end of the fiber optic light guide 306 terminates in a metal ferrule at the center of a modified Lemo connector (not shown), which passes through the docking station receptacle and enters a port in a light source.

[0027] In the connecting cable 302, the light guide 306 is covered by a thin plastic sheath, which continues into the handle portion or region 106 of the camera head 100. In the handle region 106, the light guide 306 separates or bifurcates into two equal bundles (not shown), which pass through the nose piece 102 on either side of the lens tube 212 that holds the main lens assembly 208 via curved slots in the lens holder spacer and terminate on either side of the

window 204. By splitting the light guide 306 into two bundles, a more uniform illumination for the optical system can be provided than with a single light guide.

**[0028]** At the tip of the distal end, the light guide bundles are covered in a thin-wall opaque sheath or paint, to prevent light from entering the optical system, and terminate in a ferrule that is glued into the exit ports of the distal end. The ferrules are shaped in such a way as to ensure that the angle of illumination corresponds to the direction of view of the optical system.

**[0029]** In another embodiment of the present invention, a thin-wall opaque barrier is placed between the optical system and the light guides to block stray light and prevent light from the light guide bundles from entering the optical system. The opaque barrier is preferably a metal material, however, the barrier can be made of any suitable material such as plastic, paper or other material.

**[0030]** The image sensor 210 is supported in a sensor tube 214, which is preferably stainless steel. The sensor tube 214 is permitted to slide within the lens tube 212 that holds the optical system and main lens assembly 208. The image sensor 210 is connected by a flexible printed circuit 216 to a connector 218 on the CCU board 202 located in the camera head 100, as shown in Figure 2.

**[0031]** In order to adjust the focus mode, the position of the sensor tube 214 and the image sensor 210 relative to the main lens assembly 208 is adjusted by movement of a focus rod 222 connected to the sensor tube 214. The adjustment of the focus mode is accomplished by rotating the focus mode ring 110 at the rear of the handle region 106, as detailed in Figure 3. Furthermore, the flexible printed circuit 216 has a service loop 220 over the CCU connector 218, so that the loop length for the flexible circuit 216 can adjust when the image sensor 210 and sensor tube 214 are moved by the focus rod 222.

**[0032]** A focus mode assembly includes the focus mode ring 110, which is connected, preferably by gluing, to an inner focus ring 322 with an angled slot 314. When the focus mode ring 110 is adjusted, the inner focus ring 322 with the angled slot 314 causes a pin 504 (see Figure 5) inserted into angled slot 314 to move in the direction of the camera axis. The pin 504 is attached to a linear ring 328 that is connected to one end of the focus rod 222, which focus rod 222 is then connected to the sensor tube 214 at the other end. Therefore, movement of the focus mode ring 110 results in the sensor tube 214 and the sensor 210 to moving axially, thereby

changing the sensor's position relative to the main lens assembly 208 and thereby changing the sensor's focal condition.

[0033] Due to tolerances in the lenses of the optical system, the positioning of the sensor 210 relative to the optical system has to be adjusted to obtain an optimal focal length for the focus modes. A focus calibration screw 316 and calibration spring 318 are used to adjust the length of the focus rod 222, so that the position of the sensor 210 relative to the optical system can compensate for the lens tolerances. The calibration spring 318 is positioned around the focus rod 222 and is used to prevent any backlash of the focus rod 222 during the adjustment of the focus rod 222 by the focus calibration screw 316. The calibration of the focus rod 222 to compensate for lens tolerance with the focus calibration screw 316 is typically completed during the manufacturing of the camera head 100. In addition, a focus spring 320 is used to apply a tension to the linear ring 328 and pin 504 to maintain the pin 504 in contact with a side of the angled slot 314 and is used to prevent any backlash of the focus mode assembly or the linear ring.

[0034] A spring-loaded ball 322 drops into a detent 324 in the focus mode assembly, providing tactile preset focus positions for each of the E, W and C modes discussed above. This enables the clinician to select the desired mode by feel, without the need to take his eyes off the patient. Each mode has sufficient depth of focus so that further fine adjustment within the mode is not necessary.

[0035] In another embodiment of the present invention, as shown schematically in Figure 5, a spiral slot 314 in the side of the inner focus ring 326 interacts with the focus pin 504 and linear ring 328, which linear ring 328 is then connected to the focus rod 222. The focus rod 222, as described above, is connected to the sensor tube 214 to move the sensor tube 214 longitudinally or axially as the focus mode ring 110 is rotated. Instead of the spring-loaded ball 322 and detent 324 technique shown in Figure 3 to select the focus modes, notches 506 in the spiral slot 314 corresponding to the W and C focus mode positions are pushed against by a spring loaded linear ring 328 and pin 504. The spring loading is provided by the focus spring 320 and serves two functions: it prevents backlash in the focus adjustment; and it provides a detent action caused by the focus pin 504 being forced to engage the notches 506 as the inner focus ring 326 is rotated. In addition, the E focus mode position is established or located at one end of the spiral slot 502.

[0036] In another embodiment of the present invention, the focus rod 222 can move one or more elements of the optical system relative to the image sensor 210 to obtain the different focus modes. The focus rod 222 can be connected to one or more elements of the optical system such as the negative lens or an element in the main lens assembly 208. The adjustment of the focus rod 222 for the different focus modes is accomplished in a manner similar to that described above. The adjustment of the one or more elements in the optical system is performed relative to the sensor 210 to obtain the different focus modes, in contrast to the technique for obtaining the different focus modes described above wherein the sensor 210 is moved relative to the optical system.

[0037] Figure 4 shows a second embodiment of the present invention where the image sensor 210 is connected to an extension board 404, which is rigidly connected to the CCU board 202 by a connecting arrangement 402. The connecting arrangement 402 can include any type of connection that permits axial translation of the image sensor 210 and extension board 404 without detaching from the CCU board 202. The rigidly connected image sensor 210, extension board 404 and CCU board 202 move in tandem with the CCU board 202 being connected to the camera cable 304 as previously described. The adjustment of the focus modes occurs based on the axial movement of the CCU board 202 and image sensor 210 in response to the adjustment of the focus mode ring 110 as described above except that no focus rod 222 is used and the linear ring 328 is connected to the CCU board 202. Movement of the CCU board 202 relative to the utility cable 302 is provided by the service loop in the flexible cable 308 as shown in Figure 3. In another embodiment of the present invention, the extension board 404 can be an included and integral part of the CCU board 202.

[0038] Figure 8 illustrates an alternate embodiment of the present invention, where the utility cable 302 has been replaced by a utility and communication unit. The utility and communication unit can include several different systems to satisfy all of the utility and communication requirements of the camera handpiece 100. The utility and communication unit can be detachably connected to the camera handpiece 100. The utility and communication unit can include a battery 802 to supply the power requirements of the CCU board 202 and other systems and devices in the camera handpiece 100 and the utility and communication unit. The utility and communication unit also includes a transmitter unit 804 and antenna 806 to transmit the video output signal from the CCU board 202. The transmitter unit 804, in one embodiment, may include a receiver to receive transmissions with control instructions and other information

for the CCU board 202. The transmitter unit 804 and the antenna 806 can receive their power from the battery 802. The transmitter unit 804 can transmit the video output signals using any standard wireless transmission technique, including infrared and RF transmissions, to a receiver that is preferably connected to a computer, monitor, docking station, interface unit, etc. The utility and communication unit has a light or illumination source 808 to satisfy the lighting requirements of the camera head 100. The light source 808 includes a lamp 810, a reflector 812, and a lens 814. The lens 814 transmits the light to a light guide 816, which is used to transmit the light to the tip of the nose piece 102. The battery 802 can preferably be used to supply the required power to the light source 808.

**[0039]** Figure 9 illustrates another embodiment of the camera handpiece 100 wherein the light source 808 is replaced with one or more light emitting diodes (LEDs) 900 located in the tip of the nose piece 102. The LEDs 900 can be white LEDs or a combination of colored LEDs and can be placed in the exit ports at the distal end and have the same opaque barrier or sheaths to prevent light from entering the optical system as described above. Alternatively, the LEDs 900 can be located elsewhere in the camera handpiece 100, e.g. in the handle region 106, and the light transmitted to the distal end of the camera handpiece 100 by a light guide.

**[0040]** While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.